COMPARATIVE EVALUATION OF THE EFFECT OF SURFACE MODIFICATIONS OF "*PEEK*" ABUTMENTS ON THE RETENTION OF IMPLANT SUPPORTED PROVISIONAL RESTORATIONS LUTED WITH TWO DIFFERENT LUTING AGENTS

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CERTIFICATE

This is to certify that the dissertation titled "**COMPARATIVE EVALUATION OF THE EFFECT OF SURFACE MODIFICATIONS OF *"PEEK"* ABUTMENTS ON THE RETENTION OF IMPLANT SUPPORTED PROVISIONAL RESTORATIONS LUTED WITH TWO DIFFERENT LUTING AGENTS"** is a bonafide record work done by **Dr. NIRMAL GEORGE SAIBU** under our guidance and to our satisfaction during his post graduate study period between 2008 – 2011.

This dissertation is submitted to **THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – PROSTHODONTICS AND CROWN & BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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INTRODUCTION

The use of osseointegrated dental implants is recognized as a predictable and successful treatment method for functional restoration of the fully or partially edentulous patients.[17]

Restoration over implants can be screw retained, cement retained or a combination of both. The factors that influence the different methods of fixation of prostheses include passivity of the framework, retention, occlusion, esthetics and retrievability of prosthesis. Screw retention in implant-supported prostheses was developed in response to the need for retrievability of the prosthesis. The restorative screw was designed to provide abutment - restorative joint integrity. But it has the disadvantages of compromise in esthetics due to the visibility of screw access hole. An analysis of occlusal table width and screw hole size reveals that screw holes can occupy 50% or more than the width of the occlusal table. Also it can affect the development of ideal occlusal contacts. [1,20,22,24,39,52]

The advantage of cement retained restoration include enhanced ability to develop esthetics and occlusion, easier access to restorations of posterior teeth and reduced complexity of clinical and laboratory procedures. But it has disadvantages of difficulty in retrievability of prosthesis, reduced ability to change superstructure design, difficulty in removal of excess cement in peri-implant sulcus and reduced retention in areas of limited inter-ridge space.[5,14]

Several factors influence the amount of retention in cement-retained restorations, whether they exist on natural teeth or implant abutments. These factors are taper or parallelism, surface area and height, surface finish or roughness, type of restorative material and types of cement.[22]

The cements used in fixed prosthodontics are either definitive or provisional. The choice of cement is one of the most important factors controlling the amount of retention attained. Selection of cement that is too retentive could lead to damage to implant, implant abutment, abutment screw and the prosthesis if an aggressive removal technique is used. The selection of cement that is not retentive enough could be a potential source of failure of retention of the restoration. [3,10,22,52, 60]

Studies have demonstrated that cements such as resin composite, zinc phosphate, zinc polycarboxylate, glass-ionomer, and resin modified glass-ionomer are used on implant abutment to increase retention, provide good marginal seal and to significantly enhance the cement failure loads of the prostheses. but retrievability is more difficult when definitive cements are used. Retrievability is highly desirable for cleaning and it facilitates evaluation for mobility of ailing implants. [20,39,55]

The literature reports suggested the use of provisional cements such as reinforced zinc-oxide eugenol, non-eugenol zinc-oxide and calcium hydroxide for ease of retrievability. But the problems encountered are inadequate retention to resist functional force, cement washout, mobility of restoration. Also gap between the prepared finish line and the margin of restoration causes bacterial collection and may jeopardize the health of the soft tissue and the implant or tissue interface.[5,22, 29,40,48]

Resin based cements used for luting definitive restoration on implant abutment are well documented. Literature report indicates that polyurethane and resin cements have comparative tensile bond strength on implant abutment in comparison with other zinc-oxide eugenol, non-eugenol zinc-oxide, zinc-phosphate and radiopaque reinforced glass ionomer cements. The polyurethane and resin based provisional luting agents are typically stable intraorally. Thus it is anticipated that the cement gap and the tensile bond strength of these luting agents would change less over time. So the newer polymer based resin cements could satisfy the requirements of adequate retention to resist functional force, marginal seal and also retrievability of the superstructure.[2, 11,22,48]

The factors that influence retention of cement retained restorations are the same as those for natural teeth. Abutment with nearly parallel axial walls (1^0 convergence) exhibited significant increased retention when height was increased. The change in the angle of convergence affects the retention. 10,27,39.

There are literature reports that an increase in surface roughness of prepared teeth will result in an increase in retention of cemented prosthesis, due to mechanical interlocking of the cementing medium with the roughened tooth surface. The surface modification on implant abutment can increase the retention of the cement-retained implant-supported prosthesis. Surface roughness of the implant abutment and luting agents are factors that can be controlled by the clinician. In the literature, authors have advocated different implant abutment surface modifications namely air-borne particle abrasion, abrasion with diamond rotary cutting instrument, retentive grooves to enhance the retention of cement-retained implant-supported cast copings. [2,29]

Implant abutments are available as either smooth surface or with retentive grooves. In most clinical situations to achieve parallelism, it is necessary to mill the implant abutment resulting in the loss of retentive grooves on the abutments. In clinical situations like implant in posterior region, the implant abutment height is less and milling of abutment causes further decreases in retention of the implant crown. In order to achieve retention of the restorations, the surface modifications of the implant abutments are advocated.[4,7,29,40,41]

Abutments were usually fabricated from a variety of materials, such as titanium, surgical stainless steel, gold and also from zirconia. Research on surface modification of titanium abutment has been shown to influence retention of implant restoration. Since predictable results are achieved with immediate loading of implants, there is an increasing need for use of provisional abutments. Development of a provisional prosthesis that will be stable and esthetic should begin with the initial examination and should involve all members of the implant team. To address these concerns, dentists began modifying final abutments and using them to achieve acceptable labial or buccal contours and support for the papillary tissues. Hence the PEEK abutment cost effective modality that can easily be modified to support a transitional prosthesis at the time of implant placement. Provisional abutments are available with titanium, polymer (plastic) or gold abutment. Since 1980 a newer thermoplastic polymer poly (acryl ether) ketone (PEEK) have been increasingly employed as biomaterials for trauma, orthopedics and spinal implants. PEEK is a semicrystalline thermoplastic with good mechanical properties.[9,22,30,42]

In dentistry, PEEK material is used as a plastic temporary abutment for implants in the fabrication of temporary crowns. This biocompatible material features a natural tooth colour appearance. PEEK can be also used as healing abutments. The material has low surface energy and resistance to surface modification by chemical treatments. It can be easily shaped with dental burs and used as provisional abutment in early or delayed loading situations. There is lack of research on the effect of surface modifications of PEEK abutments on retention of provisional restoration.[49,50,56]

In view of the above, the present in vitro study was conducted with the aim of comparatively evaluating the effect of surface modifications of PEEK abutments on the retention of implant-supported provisional restorations luted with two different luting agents. The luting cements employed in this study were, non-eugenol zinc oxide cement and polymeric implant cement. Also glued to this aim were the following objectives:

1. To evaluate the effect of the retentive grooves present on PEEK implant abutment on the tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations. (Group I)
2. To evaluate the effect of milling with tungsten carbide bur and air abrasion of PEEK implant abutments on the tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations. (Group II)
3. To evaluate the effect of milling with diamond abrasive of PEEK implant abutments on the tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations. (Group III)
4. To comparatively evaluate the effect of the three different surface modifications of PEEK implant abutments on the tensile bond strength of non-eugenol zinc oxide. (Between Groups I, II & III)

5. To evaluate the effect of the retentive grooves present on PEEK implant abutments on the tensile bond strength of polymeric implant cement used for luting the provisional restorations. (Group IV)
6. To evaluate the effect of milling with tungsten carbide bur and air abrasion of PEEK implant abutments on the tensile bond strength of polymeric implant cement used for luting the provisional restorations. (Group V)
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11. To compare the effect of milling with diamond abrasive on PEEK implant abutments on the tensile bond strength of non-eugenol cement with tensile bond strength of polymeric implant cement (Between Groups III, & VI)

12. To compare the mean tensile bond strength of Groups I, II and III non-eugenol zinc oxide for three different surface modification with that of poly implant cement Groups IV,V & VI.
13. To evaluate qualitatively the surface of the PEEK abutments of Groups I and IV samples (retentive grooves) using a scanning electron microscope (SEM)
14. To evaluate qualitatively the surface of the PEEK abutments of Groups II and V samples (milling with tungsten carbide bur and air abrasion with 110 µm) using a scanning electron microscope (SEM)
15. To evaluate qualitatively the surface of the PEEK abutments of Groups III and VI samples (milling with diamond abrasive) using a scanning electron microscope (SEM)
16. To correlate the qualitative and quantitative analysis of the study.

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REVIEW OF LITERATURE

Schneider RL. (1987)[51] studied to evaluate the retention of gold castings with the use of four dental cements such as zinc phosphate, polycarboxylate, glass ionomer and zinc silicophosphate to various dental implants manufactured in different materials and varying head designs. A significant difference was found among all four cements tested. Glass ionomer cement was the most retentive, followed by zinc phosphate, zinc silicophosphate, and polycarboxylate, respectively.

Felton DA et al. (1987)[16] Studied on the effect of surface roughness of crown preparation using carbide and diamonds burs on retention of cemented castings. Each crown was cemented with zinc phosphate cement with a 25kg compressive force that was held for 10 minutes. All crowns were removed parallel to the axis of draw by using Instron Universal testing machine with a crosshead speed of 0.02cm/min until failure occurred. Conclusions drawn from this study were: (1) Teeth prepared for full crowns by using diamond burs will have 31% greater retention than preparations made with carbide burs. (2) If the dentist wishes to use the more efficient carbide burs, alternative retentive features should be considered in the preparation design.

Franchina N L et al. (1991)[18] studied semicrystalline amorphous PEEK by testing the resistance to solvents that were likely to be used for surface modification reactions. The amorphous film is stable to methanol, ethanol at reflux temperatures for 24 hours and acetone at room temperature. The carbonyl group in semicrystalline PEEK is a versatile reactive handle for the surface modification of PEEK.

Mash LK et al. (1991)[35] Studied on leakage of various types of luting agents. Freshly extracted molar teeth were prepared for complete cast gold crowns cemented with zinc phosphate cement, polycarboxylate cement, glass ionomer cement, a resin luting agent, or zinc oxide-eugenol temporary cement. The specimens were tested at 1-, 6-, and 12-month intervals with radioactive 45Ca. The specimens were sectioned, auto-radiographs were made, and the marginal leakage was evaluated on a scale of 0 to 3. The results showed that zinc phosphate, polycarboxylate, and glass ionomer cements are equally suited for permanent cementation of restorations. The resin luting agent showed high initial leakage, indicating that it is not as desirable for permanent cementation purposes. The zinc oxide-eugenol cement showed increased leakage with time but is well suited for its indicated purpose, temporary cementation.

Breeding LC et al. (1992)[5] compared the retentive strengths of castings cemented to machined titanium implant abutments and to a human premolar with three provisional luting agents. And also compared the retentive strengths of cast noble metal implant abutments cemented into titanium fixtures with three permanent luting agents both dry and after storage in 0.9% physiologic saline for 30 days at 37° C. Author concluded that no significant differences were noted in retentive values between the cemented castings on the titanium abutments and the natural tooth. The Temp Bond zinc oxide-eugenol luting agent exhibited a lower mean retentive strength than the IRM reinforced zinc oxide-eugenol and

Life calcium hydroxide luting agents. Ketac Cem glass-ionomer cemented abutments that were stored in saline exhibited a significantly higher mean retentive strength than abutments cemented with either Core Paste or Resiment resin luting agents.

Dixon DL et al. (1992)[11] studied to determine the amount of die space necessary to reduce seating discrepancies of castings cemented onto implant abutments and to determine the effect that this space created for the luting-agent has on crown retention. Noble metal castings were made with 0.000 inch, 0.001 inch, 0.002 inch, and 0.003 inch spacing for pre-manufactured titanium implant abutments. The castings were cemented onto the abutment with three permanent luting agents using Core Paste, Resin cement, and Zinc Phosphate. Seating discrepancies of each casting/abutment combination were measured, and the castings were pulled from the abutments by use of tensile force. The results of this study concluded that: (1) Spacing did not reduce .retentive values for any of the specimen groups. The resin luting agent groups exhibited consistently higher retentive strength than the zinc phosphate specimens. (2) Zinc phosphate and Resiment luting agents exhibited seating discrepancy values below 25 µm with 0.001 inch luting agent spacing. Core Paste cemented specimens required 0.003 inch spacing to show values below 25µm.

Lorey RE et al. (1993)[32] studied on the potential for bonding titanium restorations by cementing with various adhesives: metal to metal, metal to enamel, and comparing with a known procedure of bonding nickel-chromium. The resin-metal adhesives used were: Infinity, Metabond, All-Bond 2, and

Panavia. These were compared with nickel-chromium cones sandblasted and bonded to nickel-chromium with Panavia. The author concluded that titanium was most effectively bonded with All-Bond 2 and Panavia, with Panavia samples significantly better than Panavia to nickel-chromium samples.

Kallus T et al. (1994)[26] investigated the possible occurrence of loose gold and abutment screws retaining full-arch osseointegrated prostheses which had been in use for at least 5 years. Author found that Gold screw loosening were related to framework misfit and was considered to be operator dependent to some extent and he recommended that full-arch fixed prostheses be retightened after 5 years.

GaRey DJ et al. (1994)[19] compared the effects of thermocycling, load-cycling, and human blood contamination on the retentive strength of five different cements for luting posts to root-form implants. This study using an Instron machine indicated that thermocycling did not significantly reduce retentive strength of the test cements, but that cyclical compressive loading did. However, the decrease is small and may not be clinically apparent. The combination of thermocycling, cyclical load-stressing, and blood contamination substantially reduced the retentive strengths for all of the cements. This suggests that blood adversely affects the retentive strength of the cements tested more than other variables.

Singer A et al. (1996)[53] conducted a 6 month to 3-year follow-up study on cement-retained implant-supported Fixed Partial Dentures. A total of 225 implants were placed (86 in maxilla and 139 in mandible) for 92 implant-supported Fixed Partial Dentures, including single tooth restorations, which were cemented using Temp-Bond or IRM. On 6-month to 3-year follow-up study, the complications encountered were cement washout, porcelain fracture, loose central screw and implant failure. The most common failure was cement washout (9.8%), porcelain fracture (2.2%), loose central screw (2.2%) and failure of one implant. This study suggests an alternative method to screw-retained prostheses; the method presented may lower the reported complications.

Hebel KS et al. (1997)[22] discussed how the choice to use screw-retained or cement-retained implants dramatically influences the occlusion and esthetics and concluded that occlusion and esthetics should not be arbitrarily discarded through the use of screws to achieve retrievability. With dramatically increased survival rates for dental implants, the once centrally important issue of retrievability takes on less significance. The proper handling of cement-retained implant prostheses provides for retrievability without compromising the occlusion, esthetics, and stress distribution to the prosthetic components and bone-implant interface. The impact of offset loading on the bone-implant interface is not well understood and further research is required in this area.

Ayad MF et al. (1997)[2] studied to determine the relationship between surface characteristics of teeth prepared for complete cast crowns and retention of respective cemented restorations. Three luting cements selected for this study: zinc phosphate cement (Fleck's), glass ionomer cement (Ketac-Cem), and adhesive resin cement (Panavia-EX). Author concluded that: (1) Cross-cut carbide burs improved retention of complete cast crowns cemented with zinc phosphate cement by 46% to 55% compared with tooth preparations completed with diamond stones or finishing burs (2) The rotary instrument used for tooth preparation did not have a significant difference on retentive strength of either glass ionomer cement or Panavia-EX resinous cement (3) Panavia-EX resinous cement provided greater tensile resistance to dislodgment of the casting and more strength regardless of type of instrumentation selected to finish the tooth preparations.

Preiskel HW et al. (1998)[46] studied on the outcome of 73 telescopic implant-supported fixed prostheses. Fifty-four prostheses were entirely cement-retained, and 19 incorporated a screw-clamping unit. Author concluded that cement-retained implant-supported telescopic prostheses provided a versatile and reliable method of treatment. However, cement-retained telescopic prostheses involving a distal cantilevered extension required the greatest postoperative maintenance.

Ramp MH et al. (1999)[48] compared the tensile bond strengths of 6 provisional luting agents such as Temp Bond, Provilink, Prototype, IRM, Neo-Temp with releasing agent, and Neo-Temp used with cemented superstructures and 1 implant system. Ten castings were fabricated and randomly paired with abutment specimens. Author concluded that: (1) Temp Bond and Provilink luting agents exhibited the lowest mean tensile bond strengths. (2) The prototype cement was significantly stronger in tension than Temp Bond and Provilink luting agents, yet had a significantly lower tensile bond strength than IRM. (3)

Neo-Temp luting agent exhibited tensile bond strength more than 3 times that of Temp Bond luting agent. (4) Neo-Temp luting agent exhibited the greatest tensile bond strengths of the luting agents tested.

Hofstede TM et al. (1999)[23] has describes an alternative technique for the fabrication of a complete-arch, cement-retained, metal-acrylic resin implant–supported fixed partial denture. The prosthesis provides an esthetic and inexpensive alternative to the traditional PFM implant-supported fixed partial denture. The cemented framework over milled abutments provides excellent prostheses retention, resistance, and stability. The cemented design ensures optimum esthetics, good occlusal contacts, and a passive fit. The use of a base metal alloy, with its high modulus of elasticity, enables the framework to be designed with smaller dimensions. Waxing the framework on the refractory cast eliminates any distortion caused by removal and handling of the wax pattern, and acrylic resin denture teeth processed with a heat-polymerized acrylic resin allows for easy and predictable repairs.

Keith SE et al. (1999)[28] studied on the marginal discrepancy of the implant-to-prosthetic-crown interface on nonsubmerged dental implants restored with either a cemented or a screw-retained approach. Author concluded that: (1) the mean marginal discrepancy of screw-retained metal-ceramic crowns on implant abutments is significantly smaller than that of cemented metal-ceramic crowns (2) the mean marginal discrepancy of metal-ceramic crowns cemented on implant abutments with glass-ionomer is significantly smaller than those cemented with zinc phosphate.

Covey DA et al. (2000)[10] studied on Effects of abutment size and luting cement type on the uniaxial retention force of implant-supported crowns. Test specimens consisted of standard and wide CeraOne (Nobel Biocare) titanium abutments and matching CeraOne gold cylinders. Type III gold cast onto the cylinders formed an attachment mechanism for testing. Three sizes of implant abutments such as standard, wide, and experimental were evaluated. Two types of cement were evaluated: a zinc phosphate permanent cement and a zinc oxide eugenol provisional cement. Author has concluded that: Permanent luting cement (zinc phosphate) produced uniaxial retention forces 2.5 to 4.7 times greater than provisional cement (zinc oxide eugenol). The increase in surface area provided by the Wide CeraOne abutment did not result in improvement in retention strengths. Abutment height and height to width ratio were positively related to retention strength, whereas an abutment’s total surface area and width were not.

Michalakis KX et al. (2000)[38] studied to evaluate the retentive strengths of 4 provisional luting agents used to cement restorations supported by 2 or 4 implants 24 hours after cementation. The provisional luting agents used for this study were: (1) ImProv, (2) Nogenol, (3) Temp Bond, and (4) Temp Bond NE. Author has concluded that: (1) Twenty-four hours postcementation, ImProv cement exhibited higher retentive strength values than Temp Bond NE, Temp Bond, and Nogenol for both the 2-unit and the 4-unit implant-supported FPDs. (2) Nogenol provisional luting agent seems to be more appropriate for the cementation of implantsupported FPDs, if retrievability is important.

Valbao FPB et al. (2001)[59] describes a simple, quick, and economical technique that makes use of a light-polymerized resin system to facilitate the retention and removal of cement-retained implant prostheses. The technique described offers restorative versatility, reversibility, and security because the hexagon gold UCLA selection allows realignment of the restoration. Moreover, the use of 2 burs with different diameters to prepare the access holes in the abutment and the use of provisional cement and light-polymerized resin facilitate removal of the restoration. An ultrasonic device or other prosthetic removal device can be used, without harming the abutment or the coping, to help remove the prosthesis once the light-polymerized resin has been removed. One disadvantage of this technique is that it may not be applicable when there is limited interocclusal distance.

Squier RS et al. (2001)[54] compared retentiveness of dental cements used with metallic implant components. The cements used for this study were zinc phosphate, resin composite, glass ionomer, resin-reinforced glass ionomer, and zinc oxide–non-eugenol. Author has concluded that: (1) Resin cement demonstrated the highest mean retentive strengths. (2) Glass-ionomer and zinc oxide–non-eugenol cements exhibited the lowest mean retentive strengths. (3) Zinc phosphate and resin-reinforced glass ionomer showed intermediate mean retentive strengths. (4) Use of an anodized abutment surface does not appear to affect retentive strength. (5) Resin and resin-modified glass-ionomer cements failed cohesively, leaving residual cement on the abutment and the implant shoulder.

Randi AP et al. (2001)[49] compared the dimensional accuracy or the fit of retrievable cement-retained implant-supported prostheses using a bis-GMA composite luting cement to a traditional wax and cast, screw-retained frame work. And evaluate the retentive strength of a retrievable cement-retained, implant-supported FPD. The control group consisted of 10 frameworks fabricated with traditional wax and casting techniques directly on the gold cylinders. Frameworks were analyzed for distortion in the z-axis and compared with retrievable cement-retained group using scanning electron microscopy and a single screw test. Results demonstrated that the retrievable cement-retained group had a decreased gap distance and improved angular distortion compared the control group. Retentive strength measurements for the cement-retained group with a direct pull-out test revealed a mean pull-out force of 65.7 kg. This retentive test supports a simplified technique of clinically luting implant-supported frameworks with adequate retentive strength.

Dumbrigue HB et al. (2002)[14] describe a technique to minimize the amount of excess cement used to lute implant restorations with the use of ITI solid abutments. The luting cement used only occlusal half the intaglio of the restoration. This amount will provide sufficient flow to the axial walls cervically and reduce the amount of excess cement along the restorative margin. The disadvantage of this technique is that incomplete sealing of the restorative margin with the luting agent may result. The resultant microgap between the implant fixture and restoration may harbor subgingival microorganisms with the potential to cause soft tissue problems.

In another technique the intaglio of the implant restoration fills with luting agent, and seats it extraorally on the practice abutment or implant analog. Wipe excess cement with a gloved finger or cotton tip applicator; immediately remove the crown from the analog, and cement it intraorally. Removal of the restoration from the analog should be in line with the long axis of the analog to avoid the elimination of too much cement from the axial walls of the restoration. The advantage of this technique is that a more complete flow of cement to the axial walls and restorative margins of the implant restoration is achieved. However, a practice abutment or abutment analog needs to be used with a luting agent that has a longer working time.

Doerr J (2002)[12] describes an accurate method for locating the implant abutment access chamber and abutment retaining screw to facilitate the removal of a cemented implant restoration. The described technique is a time-saving and accurate way to retrieve a cemented implant restoration without destroying the restoration or abutment but disadvantages are need to retain the original implant- and abutment-level casts used to fabricate the original restorations and the access hole made in the restoration must be filled and the necessary material may be dissimilar to that used to fabricate the original restoration.

Okamoto M et al. (2002)[45] describe a technique for removing a cemented superstructure from an implant abutment. A cylindrical guide hole on the lingual surface of the abutment is prepared and an access hole on the lingual side of the superstructure. To remove the superstructure from the abutment, insert a removing driver into the guide hole through the access hole. Turn the removing driver to generate a shear force to raise the superstructure. The shear force will cause the temporary cement layer to fracture and enable removal of the superstructure from the abutment. This technique is easy and reliable.

Mansour A et al. (2002)[34] compared the retention of metal copings fabricated to fit on the one-groove, one flat-sided solid titanium abutment using six different cements such as eugenol-free zinc oxide (Temp Bond NE), zinc-oxide eugenol (IRM), zinc phosphate (Hy-Bond), resin-modified glass ionomer (Protec Cem), zinc polycarboxylate (Durelon) and 10-methacryloyloxydecyl dihydrogen phosphate resin (Panavia 21). Author concluded that the results do not suggest that one cement type is better than another, but they do provide a ranking order of the cements in their ability to retain the castings. This ranking is somehow different than that obtained when the same cements are used on natural teeth. The material and surface characteristics of the implant abutment are likely responsible for this difference. Cement retention values obtained from studies that use teeth as abutments may be misleading when used in cement-retained implant-supported crowns.

Ergin S et al. (2002)[15] Compared the retentive properties of five different luting cements such as zinc phosphate (Phosphate cement), glass ionomer (Meron), resin-modified glass ionomer (Principle), resin-modified glass ionomer (Fuji Plus) and resin (Avanto) cements on base and noble metal copings. Author concluded that Fuji Plus and Avanto showed significantly higher retentive strength for nobel metal alloys and Phosphate, Principle and Meron were significantly higher retentive strength for base metal alloys.

Bernal G et al. (2003)[3] Compared the effect of 20 degrees and 30 degrees of abutment taper, total occlusal convergence (TOC), the occlusocervical dimension of 4 mm (S) and 8 mm (L), and cement such as zinc phosphate cement (Fleck's cement), zinc oxide eugenol cement(Temp-Bond), zinc oxide eugenol cement plus Vaseline, and acrylic/urethane cement (IMProv) on the tensile resistance to dislodgement of cement-retained, implant-supported restorations. Author concluded that preparations with 20 degrees of TOC and 8 mm of occIusocervical dimension had significantly higher mean retentive values for all of the cements tested. Significant differences in mean tensile strength were observed, with the highest tensile resistance seen with IMProv, followed by Fleck's cement, and the lowest tensile resistance seen with Temp-Bond plus Vaseline.

Michalakis KX et al. (2003)[39] reviewed on Cement-Retained versus Screw-Retained implant restorations. The advantages, disadvantages, and limitations have been discussed on both types of restorations. Several factors are essential to the long-term success of any implant were reviewed with regards to the both method of fixation. These factors include (1) ease of fabrication and cost, (2) passivity of the framework, (3) retention, (4) occlusion, (5) esthetics, (6) delivery, and (7) retrievability

Retrievability is advantageous for reservicing, replacement, or salvaging of the restorations and implants necessitated by (1) the need for periodic replacement of prosthodontic components; (2) loosening or fracture of the fastening screws; (3) fracture of abutments; (4) modification of the prosthesis after loss of an implant; and (5) surgical reintervention. The main disadvantage of cemented prostheses is the difficulty of their retrievability. Although retrieval is needed less often because of the dramatically increased survival rates for dental implants, the need for future removal of FPDs should not be overlooked. For this reason, provisional luting agents are widely used for the cementation of cement-retained restorations. From various laboratory researches it was concluded that there is a statistically significant difference in the tensile strengths of provisional cements. Clinicians are encouraged to use the least retentive cements so that prostheses can be retrieved if necessary.

Zidan O et al (2003)[61] The retention of complete crowns prepared with three different tapers and luted with four different cements. One hundred twenty sound human molar teeth were assigned randomly to 1 of 12 groups. The groups represented the 4 cements: zinc phosphate (Fleck's), a conventional glass ionomer (Ketac-Cem); 2 adhesive resin cements (C&B Metabond and Panavia); and 3 tapers of 6-degrees, 12-degrees, and 24-degrees within each cement. Crowns were cast with a high noble alloy. The 6-degree taper was considered the control within each cement group. Retention was measured (MPa) by separating the metal crowns from the prepared teeth under tension on a universal testing machine. Analysis of variance was used to test the main effects on the retentive strength of full crowns, namely cements, tapers, and failure modes. Author concluded that within the limitations of this study, the retentive values of the adhesive resins at 24-degree taper were 20% higher than the retentive values of the conventional cements at 6-degree taper. The use of resin luting agents yielded retention values that were double the values of zinc phosphate or conventional glass ionomer cement.

Rajan M et al. (2004)[47] describe a method to fabricate a retrievable, cement- and screw-retained implant crown for a single molar. A complete arch closed tray impression using the indirect transfer coping assembly made. The implant analog screwed to the transfer coping and cast is poured using Type IV stone. The friction fit abutment is attached to the implant analog. The abutment is prepared for a metal-ceramic crown. The hexagonal screwdriver is placed in position to maintain the screw access channel. Wax pattern is made for the implant crown coping and casting is done and verified intraorally. With keeping the occlusal screw access channel open ceramic is added incrementally. Using the crown as a repositioning device, the abutment to the implant is screwed and the hexagonal screwdriver is passing through the open screw access channel. The abutment screw is tightened and torque. The crown with a definitive cement, such as zinc phosphate, glass ionomer, or resin cement is cemented. The excess cement is removed through the access opening with an explorer and closes the screw channel with gutta-percha. Author suggests that, this is a simple, practical, and effective technique for fabricating a retrievable cemented implant restoration has been described. The technique facilitated predictable prosthesis retrieval and allowed for removal of excess cement.

Tomson P. L. M. et al (2004)[57] reported a patient who developed peri-implant bone loss around 2 maxillary endosseous root-form implants after restoration with cement-retained single crowns. Significant localized bone loss occurred around 1 of the implants due to retained excess cement. Reparative treatment consisted of a guided bone regeneration technique. Following a 9-month period of submerged healing, the implants were re-exposed and restored to complete function.

Maydan. L et al (2004)[36] evaluated the effect of the addition of circumferential grooves to the abutments on the retention of cemented crowns in an implant system using two types of cements. 52 implant abutments (MIS, Israel) were divided into four groups: no grooves, one groove, two grooves and three grooves. Other than the number of grooves, all abutments were identical. 13 NiCr identical casts were prepared to fit all 52 abutments. The casts were cemented to each group of abutments using a temporary cement (Tempbond NE, Peterborough, UK) and a permanent cement (Harvard Cement, Harvard Dental, Germany). The casts were separated from the abutments using an Instron testing machine (crosshead speed of 0.5 cm/min) and the maximum retentive forces were recorded. The data were subjected to one way-ANOVA and Tukey tests. The mean retentive forces for Tempbond NE cement were 168±32 N for no grooves,192±33 N for one groove, 208±23 N for two grooves and 246±17 N for three grooves. The mean retentive forces for Harvard cement were 343±60 N for no grooves, 579±30 N for one groove and 540±38 N for two grooves (results for three grooves have not been obtained yet). For Tempbond cement groups, retention values were increased in accordance to the number of grooves ($p<0.001$). For Harvard cement, addition of one and two grooves increased retention values, similarly ($p<0.001$). The findings suggest that addition of circumferential grooves to implant abutments increases the retention of crowns cemented with Tempbond as well as Harvard cements. These grooves can be crucial for the retention of crowns cemented to short abutments of implant systems.

Bresciano M. et al. (2005)[6] studied to evaluate the retention of four cements such as zinc-phosphate, zinc oxide-eugenol, polyurethane resin with and without vaseline cemented on Procera titanium abutments of 5, 7, and 9 mm of height, and of 0 degrees , 4 degrees , and 8 degrees of convergence angle. Author concluded that the most retentive cement was zinc-phosphate, followed by polyurethane, polyurethane plus vaseline, and zinc oxide-eugenol.

Maeyama H. et al (2005)[33] compared the retentive strength of metal copings on prefabricated abutments with five different luting cements such as zinc oxide-eugenol-free temporary, zinc phosphate, glass ionomer, resin-reinforced glass ionomer, and composite resin cements. Author concluded that the retentive strength of metal copings on implant abutments is somewhat different from those of conventional cemented restorations on natural teeth. These differences may be influenced by differences in surface roughness and the height of the abutment.

Kim Y et al. (2006)[29] compared the retention of provisional autopolymerizing acrylic resin implant-supported single restorations with combinations of different implant abutment surface conditions such as abraded with 50-mm aluminum oxide and roughened with a medium-roughness diamond rotary cutting instrument and provisional luting agents such as TempBond,

TempBond NE, Life, and Zone. Author concluded that Surface modification of an implant abutment by airborne-particle abrasion or diamond rotary cutting instrument did not improve retention of a provisional acrylic crown when Life or Zone was used as the luting agent. Airborne-particle abrasion may be an effective method to increase retention of a provisional acrylic crown when TempBond NE is used.

Kaar D et al. (2006)[25] evaluates the effect of fatigue damage on the force required to remove a restoration in a cement-retained implant system using with three types of luting cements (ImProv, UltraTemp, and TempBond). Author concluded that TempBond luting agent as the material of choice for provisional cementation because it allows easier removal of the prosthesis and maintains enough retention to prevent loosening of the restoration. ImProv had the highest retentive value before and after the two cycles, and TempBond had the lowest. UltraTemp had the highest percentage of retentive value lost. TempBond had no significant loss under loading even though initially it was the weakest.

Chee et al. (2006)[8] discussed the clinical perspective and the advantages and disadvantages of both screw-retained and cement-retained implant prosthesis under the heading of aesthetics, retrievability, retention, implant placement, passivity, provisionals, occlusion, immediate loading, impression procedures, long term treatment planning. Author concluded that although there is no clear advantage of one type retention over the other, it is the clinical preference to use screw retention as primary mode when restoring implants.

Michalakis K et al. (2007)[40] compared the effects of thermal cycling and surface roughness of metal implant abutments and the intaglio surface of the copings on the retentive properties of 4 provisional luting agents commonly used in the cementation of implant-retained fixed partial dentures (FPDs). Within the limitations of this in vitro study it was concluded that: Thermal cycling had a detrimental effect on the retentive properties of all cements tested. Air abrasion significantly increased the cement failure loads of the provisional luting agents used in the study and seems to be an effective way of increasing the retention of implant-retained FPDs. Nogenol exhibited the lowest mean retentive values after thermal cycling and after air abrasion for both the 2- and 4-unit FPD models. Improv exhibited the highest mean retentive strength for both the 2- and 4-unit FPDs after both the thermal cycling and air abrasion treatments.

Kurtz S M et al. (2007)[30] studied about the PEEK employed as biomaterials for trauma, orthopedic and spinal implants also discussed about the structure, mechanical properties and chemical properties and chemical resistance to PEEK biomaterials. This review concluded that PEEK had greatest clinical impact in the field of spine implant design, total joint replacement and fracture fixation implants. Radiolucency and inertness of PEEK biomaterials must be a platform to further develop bioactive materials with the blending of hydroxyapetite and tricalcium phosphate into sintered PEEK

Lawson CN et al. (2007)[31] measured the retention and flexural strength of base metal alloy castings to dentin provided by 8 provisional cement. This study has mainly focused on current resin based and zinc-oxide non-eugenol based cement. Pemier implant cement, SensiTemp, TNE were the resin based cement and GC Temp, TempBond NE, TempoSIL, TempoCem, and Zone were zinc-oxide non-eugenol based cement. Author concluded that all three resin based cement were highest crown retention strength and flexural strength comparatively oxide non-eugenol based cement

Sheets JL et al. (2008)[52] compared the retentive nature of common dental cements that have been adapted for use in the implant abutment cement-retained crown technique. Ten regular diameter implant analogs were embedded in stainless steel disks. Unmodified CRC abutments were attached and torqued to 30 Ncm. Test crowns were waxed and cast with base metal alloy. Castings were fitted, cleaned with aluminum oxide, and steam cleaned prior to application of the cement. The cements used were: (1) Temp Bond, (2) UltraTemp, regular, (3) UltraTemp firm, (4) ImProv with petroleum jelly coating of crown, (5) ImProv without petroleum jelly, (6) Premier Implant with KY Jelly coating of abutment, (7) Premier Implant without KY jelly, (8) TR-2, (9) Fleck's, (10) Ketac Cem Aplicap, and (11) Fuji Plus Capsule. Within the limitations of this in vitro study, it is not suggested that any one cement variety is better than another at retaining cement-retained crowns (CRCs) to implant abutments or that a threshold value must be accomplished to ensure retention. The ranking of cements presented is meant to be a discretionary guide for the clinician in deciding the amount of desired retention between castings and implant abutments.

Ichikawa T et al. (2008)[24] describe two methods for improving the retrievability of cement-retained implant superstructures. One method involves incorporating a removal screw in the superstructure and the second method uses a small dimple on the abutment, accessed through a vent in the superstructure. The technique uses a large removal screw in the same dimension as the gold screw positioned parallel to the long axis of the abutment. A small removal screw positioned at an oblique angle, thereby allowing the removal screw access to nonesthetic and nonocclusal contact areas. The rotating lever system provides the convenience of prosthesis retrievability as well as venting for removal of excess provisional cement.

Urdaneta RA et al. (2008)[58] studied on the integrated abutment crown (IAC) technique for the fabrication of single-tooth implant-supported crowns where the abutment and the crown are one unit. The abutment-crown complex is connected to the implant with a locking taper. This technique does not use cement to retain the crown or screws to retain the abutment. Author concluded that the screw less and cementless implant restorations showed a survival rate of 98.7%, excellent marginal adaptation with a cementless interface, color stability, and a reduced number of prosthetic components. Plaque accumulation was observed around the crown material. The surface texture had higher roughness. IACs located between a tooth and implants were 2.65 times more likely to have postinsertion complications and IACs with incorrect anatomic form (overcontoured) were 3.26 times more likely to have postinsertion complications.

Mehl C. et al. (2008)[37] studied on the retrievability of cemented implant crowns using two different removal devices using five cements such as eugenol-free zinc oxide (Freegenol), zinc phosphate (Harvard), glass ionomer (Ketac Cem), polycarboxylate (Durelon) and so-called self-adhesive resin (RelyX Unicem) cement. Author concluded that zinc phosphate and glass ionomer cement might be suitable for a so-called 'semipermanent' (=retrievable) cementation, while polycarboxylate seems to provide the most durable cementation.

Dudley JE. (2008)[13] studied on the influence of compressive cyclic loading on the physical retention of cast crown copings cemented to Straumann synOcta implant abutments. Author concluded that, with a resin, glass ionomer and temporary cement was significantly affected by cement type but not compressive cyclic loading. Resin cement is the cement of choice for the definitive non-retrievable cementation of cast crown copings to Straumann synOcta implant abutments out of the three cements tested.

Okada H et al. (2009)[44] studied on development of a new temporary luting agent consisting of PEMA and eugenol-residue ratio and bond strength of luting cements such as for abutment materials and assess their clinical applicability. The residue ratio of PE 1.0 on the abutment material after temporary restoration removal was lower than those of comparable temporary luting agents (polycarboxylate cement type, zinc oxide-eugenol cement type), and no residue was recognized for PE 1.6. On bond strength, those of the resin-modified glass ionomer cement and resin cement for the resin core and bovine dentin surface after the removal of trial agents tended to be the same or increase in comparison to commercial temporary luting agents. Author concluded that the trial agents were suitable for clinical use

Schmidlin P R et al. (2010)[50] studied on the effect of a composite resin cement and an adhesive composite system to a non treated PEEK surface, acid etching surface with sulfuric acid, sand blasting with aluminium oxide powder 110µm, silica coating using the rocatec system and polished sand blasted CP titanium. Shear bond strength was measured in a shear testing machine and failure was assessed. No bond Conclusion drawn from this study was no bond could be established on any PEEK surface except specimens with sulfuric acid.

MATERIALS AND METHODS

This in vitro study was conducted for the comparative evaluation of the effect of surface modifications of PEEK implant abutments on the retention of implant-supported restoration with two different cements (polymeric implant cement and non-eugenol zinc oxide cement).

Materials used for this study:

- Torque ratchet (UniTi, Equinox medical technologies, Holland)(Fig. 1a)
- Ratchet hex driver (UniTi, Equinox medical technologies, Holland) (Fig. 1b)
- Hand hex driver (UniTi, Equinox medical technologies, Holland) (Fig. 1c)
- PEEK implant abutment (Bio temp, UniTi, Equinox medical technologies, Holland) (Fig. 1d)
- Implant analog (UniTi, Equinox medical technologies, Holland)(Fig. 1f)
- Implant cover screw (UniTi, Equinox medical technologies, Holland) (Fig.1g)
- Polyvinyl siloxane putty and light body impression material (Aquasil, Dentsply, USA)(Fig. 2)
- Auto polymerizing acrylic resin (DPI, India) (Fig. 5)
- Tooth coloured autopolymerizing acrylic resin(DPI, India) (Fig.15a)
- Tungsten carbide milling bur (0110.023HP Edenta, Switzerland) (Fig. 7b)
- Diamond abrasive (5218/037,Edenta, Switzerland) (Fig. 7c)
- Aluminum oxide powder (110 µm,Delta, India) (Fig. 9b)

- Non-eugenol zinc oxide cement(Rely X Temp NE, 3M ESPE, USA) (Fig.16a)
- Polymeric implant cement with automixing tips (Implacem, Equinox Medical Technologies B. V, Holland) (Fig. 17a)
- 1kg weight stones (Giri Brothers, Chennai, India) (Fig. 19)
- Artificial saliva(Wet mouth, ICPA health, India) (Fig. 22)

Equipments used for this study:

1. Dental surveyor (Bego, Germany) (Fig. 4a)
2. Micromotor with handpiece for milling (Sprint, Heraeus Kulzer Dental, Germany) (Fig.7a)
3. Sandblaster (Delta, India) (Fig. 9a)
4. Scanning electron microscope (Hitachi d3400, Japan) (Fig. 10)
5. Universal testing machine (Lloyd instruments,Farnham,U.K.)(Fig. 25)

Scanning electron microscope

The scanning electron microscope (SEM) (Fig. 10) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a scan pattern.

The types of signals produced by an SEM include secondary electrons and back scattered electrons (BSE) and transmitted electrons.

Metal objects require little special preparation for SEM except for cleaning and mounting on a specimen stub. Nonconductive samples usually coated with an ultrathin coating of electrically-conducting material, commonly gold, deposited on the sample either by low vacuum sputter coating or by high vacuum evaporation. Coating prevents the accumulation of static electric charge on the specimen during electron irradiation.

For PEEK, Carbon double-sided conductive tapes are used for electrical conductivity and offer a clean background.

Universal testing machine:

To obtain the tensile bond strength of the specimens, universal mechanical testing machine (Lloyd instruments, Farnham, U.K.) (Fig. 25) was used. This machine rests on a table top. It consists of a lower chamber, upper chamber, a display board to display the amount of force needed and a computer. The upper member houses the hydraulic pressure machine. It also has the fixture to hold the custom-made hook embedded to the clear autopolymerizing resin block, (Fig. 26) on which a stylus can be attached for determining the fracture bond strength. The lower portion has a bench vice test specimen fixture to hold the test specimens. The whole unit is attached to a computer for recording and converting data as required.

METHODOLOGY

The following methodology was adapted for preparation and for testing the samples.

1. Preparation of silicone mold
2. Positioning of the implant analog in the mold
3. Stabilizing the implant analog with auto polymerizing acrylic resin
4. Fastening the implant abutment to implant analog
5. Surface modification of test abutment samples
6. Scanning electron microscopy of surface topography of abutments
7. Fabrication of provisional acrylic copings
8. Cementation of acrylic copings to implant abutments
9. Aging of test samples with cemented copings
10. Testing the samples for tensile bond strength
11. Data tabulation and statistical analysis

1. Preparation of silicone mold:

Silicone mold is necessary for the fabrication of the acrylic blocks of standard dimension for the positioning and stabilizing the implant analog (Fig.1f). This mold is prepared from the custom fabricated acrylic block of 25 x 25 x 15 mm dimensions. The silicone mold was prepared with polyvinyl siloxane with an internal mold space of 25 x 25 x 15 mm.(Fig.3)

2. Positioning of the implant analog in the mold:

The silicone mold (Fig.3) was positioned on the surveying table of a dental surveyor (Bego, Germany) (Fig 4a) with its base parallel to the floor. A cover screw (UniTi, Equinox medical technologies, Holland) (Fig.1g) was attached to the implant analog with a hand hex driver (UniTi, Equinox medical technologies, Holland).(Fig.1c) With the help of a straight mandrel an implant analog (Fig.1f)with cover screw was attached to long axis of the surveying arm of the dental surveyor. The surveying arm was adjusted to position the implant analog in the centre of the silicone mold such that the platform for the implant abutment was 1mm above the surface of silicone mold (Fig.4b)

3. Stabilizing the implant analog with auto polymerizing acrylic resin:

After positioning the implant analog,(Fig.4b) the space around the analog was filled with clear auto polymerizing acrylic resin (DPI, India)(Fig.5). The silicone mold(Fig.3) was completely filled such that the platform of the implant abutment was 1mm above the surface of the resin block. The resin was allowed to polymerize and the resin block removed from the silicone mold. 60 clear acrylic blocks were made, each stabilizing one implant analog.

4. Fastening the implant abutment to implant analog:

A PEEK implant abutment (Bio temp, UniTi, Equinox medical technologies, Holland) (Fig.1d) was placed on the implant analog (Fig.1f) and the abutment screw was first tightened with hand hex driver (UniTi, Equinox medical technologies, Holland) (Fig.1c) (Fig.6a) and followed by tightening to 25 Ncm of torque with a ratchet hex driver (UniTi, Equinox medical technologies, Holland) (Fig.1b) and torque ratchet (UniTi, Equinox medical technologies, Holland) (Fig.1a) (Fig.6b) device. 60 such samples were obtained in a similar manner.

5. Surface modification of test abutment samples:

The test samples were divided into six groups as follows:

Groups I and IV: (PEEK abutments with retentive grooves) (Fig.8a) Twenty Straight PEEK abutments with horizontal retentive grooves were retained unaltered as obtained from the manufacturer. The numbers of grooves were 5 per abutment. Each groove was 0.5mm deep and 1mm wide. The height of the PEEK abutment was 7mm.

Groups II and V: (PEEK abutments milled with tungsten carbide bur and air abraded with aluminum oxide powder 110µm)(Fig.8b) Twenty test samples were kept on surveying table of dental surveyor. A micromotor (Sprint, Heraeus Kulzer Dental, Germany) with a milling tungsten carbide bur (01 10.023HP, Edenta, Switzerland) (Fig.7b) of 2^{o} taper was attached to the dental surveyor (Bego, Germany). The PEEK implant abutment surface was milled to obtain a uniform surface eliminating the grooves and obtaining a 2^{0} taper circumferentially. A shoulder type of margins were given for all test samples. The area below the abutment margins were then covered with polyvinyl silicone putty impression material (Fig 2). Air abrasion was done on the PEEK implant abutment surface with 110µm size aluminum oxide powder (Delta, India) at 50 lb pressure in a sandblaster (Delta India) (Fig 9 a & b).The distance of nozzle from the abutment was maintained as 10mm. Putty material prevented sandblasting of abutment surface below the finish line.

Groups III and VI(PEEK abutments milled with diamond abrasive) (Fig.8c) Twenty test samples were kept on surveying table of dental surveyor. A micromotor (sprint, Heraeus Kulzer Dental, Germany) was attached to the dental surveyor (Bego, Germany) (Fig.7a). The implant abutment surface were milled using a diamond abrasive (5218/037, Edenta, Germany) (Fig.7b) to obtain uniform surface and 2^0 taper circumferentially. The coarse diamond abrasive was used for milling (The diamond particle size were 125 -150 µm). Shoulder type of margins were given for all test samples. The same procedure was followed for the 20 test samples of the Groups II and V.

6. Scanning electron microscopy of surface topography of abutments

Three additional PEEK abutments with surface modifications were subjected to an SEM study at a magnification of 2000x. (Fig.10 & 11)

7. Fabrication of provisional acrylic copings:

Designing of the copings done using inlay wax (Fig.12). The wax patterns (Fig.13a) were designed with a thickness of 1mm at the finish line. Wax loops were attached to the flat occlusal surface of the patterns. An index (Fig.13b) design were designed using Polyvinyl siloxane putty and light body impression material (Aquasil, Dentsply, USA) (Fig.2) for the fabrication of acrylic copings.

Spacer was not applied on the abutment surface to simulate clinical condition of making provisional restorations. Using the index (Fig.14) obtained from the wax patterns, acrylic copings (Fig.15b) were fabricated using tooth coloured auto polymerizing acrylic resin (DPI, India)(Fig.15a). The acrylic resin was mixed in the manufacturer recommended ratio and the index filled with the acrylic resin. It was then seated over the abutment and allowed to polymerize to obtain the acrylic copings. After 5 minutes of polymerization, the index was removed and the coping retrieved. Internal surface was inspected for nodules and fit of coping at margin verified. This procedure was followed to obtain 60 acrylic copings.

8. Cementation of acrylic copings to implant abutments:

A custom-made autopolymerizing acrylic resin table (Fig.20) was fabricated to support the two 1kg weight stones (Giri Brothers, Chennai, India) (Fig.19) to provide uniform load onto the copings during cementation, and attached to the surveying arm of the dental **s**urveyor (Bego, Germany)(Fig.4a)**.** The test samples were placed on the surveying table. The non-eugenol zinc oxide cement (rely x temp NE, 3M ESPE, USA) (Fig.16a & b) was manually mixed (Fig.16c) and used for luting acrylic copings (Fig.16d) of Groups I, II and III. Polymeric implant cement (Implacem, Equinox Medical Technologies B. V, Holland) (Fig.17a) was auto-mixed (Fig.17b) and dispensed into the intaglio surface of the acrylic copings and cemented onto the abutments of Groups IV, V and VI. The load of 2 kg were applied for proper cementation.(Fig.21)

9. Aging of test samples with cemented copings:

All test samples of Groups I,II,III,IV,V and VI after cementation were kept in artificial saliva (Wet mouth, ICPA health, India) (Fig.22) for 24 hours at room temperature for aging before subjecting to the testing procedure to simulate clinical condition (Fig.23).

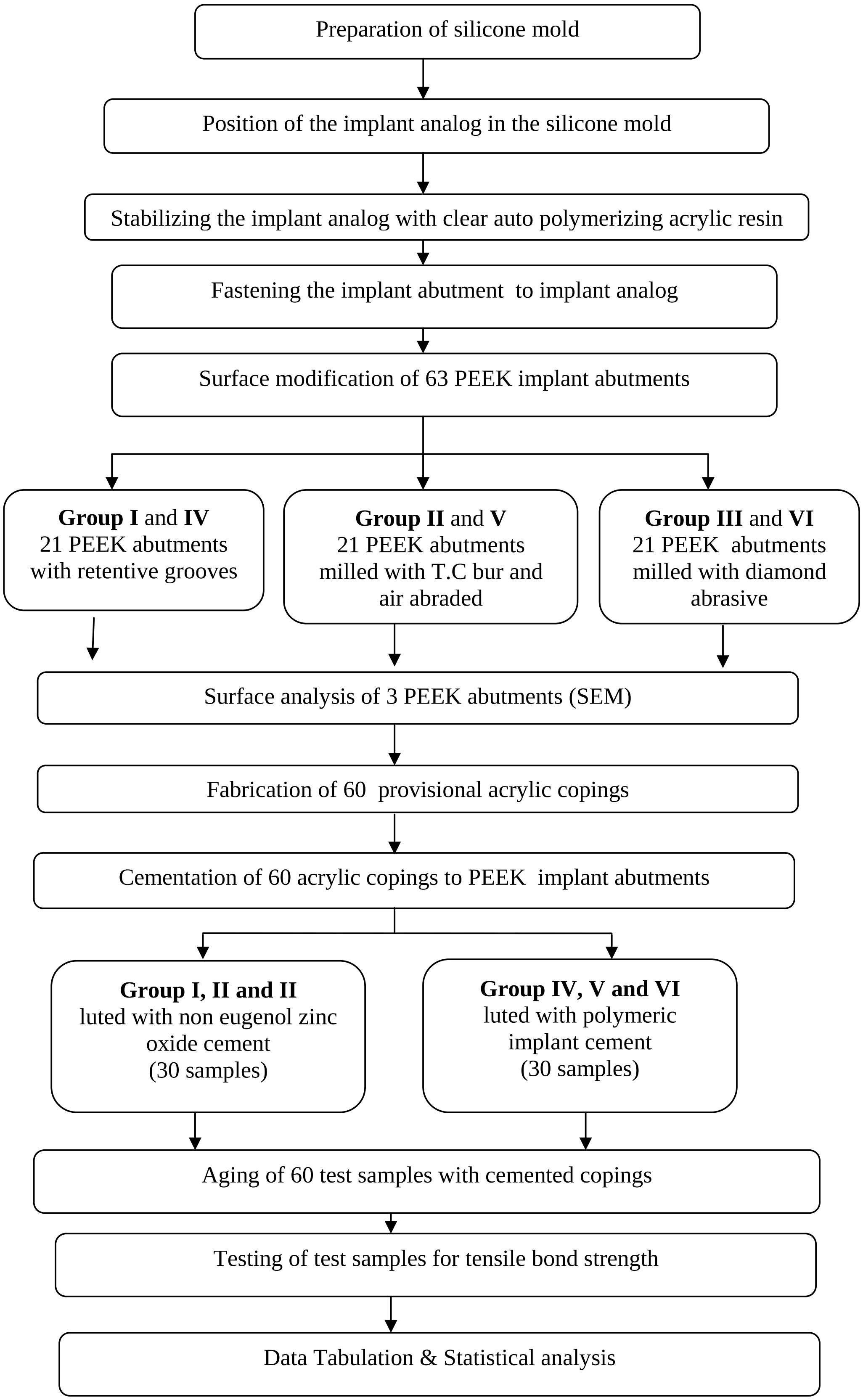
10. Testing the samples for tensile bond strength:

The universal mechanical testing machine (Lloyd instruments, Farnham, U.K.) (Fig.25) was used to determine the tensile bond strength of cements. The test samples were fixed to the sample fixture at the lower chamber of the universal mechanical testing machine. The resin block holding the custom-made hook (Fig.24) was attached to the upper chamber. The custom-made hook was attached to the loop of the test specimen (Fig.26). Each specimen were pulled from the abutments with a 500kg load cell in the universal testing machine at a crosshead speed of 5mm/min, until the copings debonded from the abutments. The computer attached to the testing machine recorded the force at which this debonding occurred (Fig.27 & 28). From this, the tensile bond strength of non-eugenol zinc oxide cement and polymeric implant cement of all test samples were recorded in newton (N).

11. Data tabulation and analysis:

The basic data and mean values obtained were tabulated and subjected to statistical analysis. The SPSS (SPSS for Windows 15.0 SPSS Software Corp., Munich, Germany) software package was used for statistical analysis. Above followed by Tukey HSD post hoc analysis was done to obtain multiple comparisons between the groups.

METHODOLOGY FLOW CHART



RESULTS

This in vitro study was conducted for the comparative evaluation of the effect of surface modification of PEEK abutments on the retention of implant-supported provisional restorations luted with non-eugenol zinc oxide cement and polymeric implant cement.

A total of 60 PEEK implant abutments of same size were selected (height 7mm). The selected implant abutments were divided into six groups of ten samples each according to the type of surface modifications on implant abutments and two type of cements used for cementation of acrylic copings. Groups I and IV had retentive grooves on the PEEK abutment surface, PEEK abutments of Groups II and V were milled with tungsten carbide bur and air abraded with aluminum oxide and Groups III and VI PEEK abutments were milled with sintered diamond abrasive. The acrylic copings of Groups I, II & III were luted onto the abutments with non eugenol zinc oxide cement and those of Groups IV,V & VI were luted with polymeric implant cement. All the 60 test samples were subjected to testing for tensile bond strength in a universal testing machine. 3 additional PEEK abutments were selected and subjected for SEM analysis.

The above results obtained from the present study were subjected to statistical analysis:

- The SPSS (SPSS for Windows 15.0 SPSS Software Corp., Munich, Germany) software package was used for statistical analysis.
- Mean and standard deviation were estimated for each study group.
- One way ANOVA and Tukey – HSD analysis were performed.
- Table 1, 2, and 3shows basic data of tensile bond strength for Groups I, II, and III (non-eugenol zinc oxide)samples respectively.
- Table 4 shows the comparison of mean and standard deviation of tensile bond strength (non eugenol zinc oxide cement) for Groups I, II and III by one-way ANOVA.
- Table 5 shows the comparison of mean tensile bond strength (non eugenol zinc oxide cement) of Groups I & II, Groups I & III and Groups II & III using Tukey-HSD procedure.
- Table 6, 7 and 8 shows basic data of tensile bond strength for Groups IV, V and VI (polymeric implant cement) samples respectively.
- Table 9 shows the comparison of mean and standard deviation of tensile bond strength (polymeric implant cement) for Groups IV, V and VI by One-way ANOVA.

- ❖ Table 10 shows the comparison of mean tensile bond strength (polymeric implant cement) of Groups IV & V, Group IV & VI and Group V & VI using Tukey-HSD procedure.
- ❖ Table 11 shows the comparison of mean tensile bond strength (non eugenol zinc oxide cement and polymeric implant cement cement) of Groups I & IV, Groups II & V and Groups III & VI using Tukey-HSD procedure.
- ❖ Graph 1 shows the basic data of tensile bond strength of Group I (PEEK abutments with retentive grooves and cemented with non-eugenol zinc oxide cement) samples.
- ❖ Graph 2 shows the basic data of tensile bond strength of Group II (PEEK abutments milled with tungsten carbide bur, air abraded and cemented with non eugenol zinc oxide cement) samples.
- ❖ Graph 3 shows the basic data of tensile bond strength of Group III (PEEK abutments milled with diamond abrasive and cemented with non eugenol zinc oxide cement) samples.
- ❖ Graph 4 shows the comparison of mean tensile bond strength of Groups I, II & III .
- ❖ Graph 5 shows the basic data of tensile bond strength of Group IV (PEEK abutments with retentive grooves and cemented with polymeric implant cement cement) samples.

- Graph 6 shows the basic data of tensile bond strength of Group V (PEEK abutments milled with tungsten carbide bur, air abraded and cemented with polymeric implant cement) samples.
- Graph 7 shows the basic data of tensile bond strength of Group VI (PEEK abutments milled with diamond abrasive and cemented with polymeric implant cement) samples.
- Graph 8 shows the comparison of mean tensile bond strength of Groups IV, V & VI.
- Graph 9 shows the comparison of mean tensile bond strength of Groups I & IV, II &V, III & VI.

Table 1 Basic data of tensile bond strength for Group I (PEEK abutments with retentive grooves luted with non-eugenol zinc oxide cement) samples

Sample No.	Maximum Load (N)
1	22.39
2	29.12
3	21.50
4	22.76
5	22.14
6	23.09
7	28.27
8	27.25
9	23.92
10	25.55
Mean	24.60

INFERENCE: Table 1 shows the maximum tensile bond strength for implant PEEK abutments with retentive grooves was 29.12 newton and minimum was 21.50 newton. The mean tensile bond strength was 24.60 newton.

Table 2 Basic data of tensile bond strength for Group II (PEEK abutments milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide powder luted with non-eugenol zinc oxide cement) samples

Sample No.	**Maximum Load (N)**
1	20.83
2	22.89
3	21.74
4	22.49
5	32.52
6	29.42
7	22.93
8	31.21
9	32.56
10	30.73
Mean	26.74

INFERENCE: Table 2 shows the maximum tensile bond strength for surface modified PEEK implant abutment with tungsten carbide bur and air abraded was 32.56 newton and minimum was 20.83 newton. The mean tensile bond strength was 26.74 newton.

Table 3 Basic data of tensile bond strength for Group III (PEEK abutments milled with diamond abrasive luted with non-eugenol zinc oxide cement) samples

Sample No.	**Maximum Load (N)**
1	49.61
2	39.31
3	41.62
4	44.62
5	57.31
6	39.81
7	53.27
8	56.56
9	45.74
10	45.86
Mean	47.37

INFERENCE: Table 3 shows the maximum tensile bond strength for surface modified PEEK implant abutment with diamond abrasive was 57.31 newton and minimum was 39.31 newton. The mean tensile bond strength was 47.37 newton.

Table 4 Comparison of mean and standard deviation of tensile bond strength for Groups I, II and III by one-way ANOVA (non-eugenol zinc oxide cement)

Group	**Number of samples**	**Mean**	**Standard Deviation**	**Overall P-Value**
Group I	10	24.60	2.76	<0.001**
Group II	10	26.74	4.92	
Group III	10	47.37	6.59	

* Note : If P- value is < 0.05, then the difference between the mean values are statistically significant

** denotes statistically highly significant (P -value <0.001)

INFERENCE: The mean tensile bond strength of Group I was 24.60 newton, Group II was 26.74 newton and Group III was 47.37 newton. On comparison between three groups the results were found to be statistically highly significant.

Table 5 Comparison of mean tensile bond strength of Groups I & II, Groups I & III and Groups II & III using Tukey-HSD procedure (non-eugenol zinc oxide cement)

Group	Number of samples	Mean	Standard Deviation	P-Value
Group I	10	24.60	2.76	0.243
Group II	10	26.74	4.92	
Group I	10	24. 60	2.76	0.008*
Group III	10	47.37	6.59	
Group II	10	26.74	4.92	0.001 **
Group III	10	47.37	6.59	

* Note : If P- value is < 0.05, then the difference between the mean values are statistically significant

** denotes statistically highly significant (P -value <0.001)

INFERENCE:The mean difference between Groups I & II, Groups I & III and Groups II & III by using the Post-hoc analysis (Tukey-HSD procedure) the results of Groups I & II was found to be statistically insignificant and Groups I & III andGroups II & III were found to be statistically significant.

Table 6 Basic data of tensile bond strength for Group IV (PEEK abutments with retentive grooves luted with polymeric implant cement) samples**.**

Sample No.	**Maximum Load (N)**
1	59.25
2	64.56
3	65.97
4	67.71
5	62.98
6	49.04
7	59.87
8	60.31
9	56.98
10	53.51
Mean	60.02

INFERENCE: Table 6 shows the maximum tensile bond strength for PEEK implant abutment with retention grooves was 67.71 newton and minimum was 49.04 newton. The mean tensile bond strength was 60.02 newton.

Table 7 Basic data of tensile bond strength for Group V (PEEK abutments milled with tungsten carbide bur, air abraded with aluminum oxide powder 110µm and luted with polymeric implant cement) samples

Sample No.	Maximum Load (N)
1	61.92
2	42.52
3	68.10
4	46.39
5	44.56
6	43.05
7	42.88
8	65.54
9	39.36
10	41.43
Mean	49.56

INFERENCE: Table 7 shows the maximum tensile bond strength for surface modified PEEK implant abutment with tungsten carbide bur and air abraded was 68.10 newton and minimum was 39.36 newton. The mean tensile bond strength was 49.56 newton

Table 8 Basic data of tensile bond strength for Group VI (PEEK abutments milled with diamond abrasive luted with polymeric implant cement) samples

Sample No.	**Maximum Load (N)**
1	49.61
2	55.12
3	58.74
4	56.13
5	69.23
6	56.04
7	70.20
8	68.72
9	57.81
10	61.29
Mean	60.29

INFERENCE:Table 8 shows the maximum tensile bond strength for surface modified PEEK implant abutment with diamond abrasive was 70.20 newton and minimum was 49.61 newton. The mean tensile bond strength was 60.29 newton.

Table 9 Comparison of mean and standard deviation of tensile bond strength for Groups IV, V and VI by one-way ANOVA (polymeric implant cement)

Group	Number of samples	Mean	Standard Deviation	P-Value
Group IV	10	60.02	5.74	0.009*
Group V	10	49.56	11.02	
Group VI	10	60.29	6.95	

* Note : If P value is < 0.05, then the difference between the mean values are statistically significant

** denotes statistically highly significant (P-value <0.001)

INFERENCE: The mean tensile bond strength of Group IV was 60.02 newton, Group V was 49.56 Newton and Group VI was 60.29 newton. On comparison between three groups the results were found to be statistically significant

Table 10 Comparison of mean tensile bond strength of Groups IV & V, Groups IV & VI and Groups V & VI using Tukey-HSD procedure (polymeric implant cement)

Group	Number of samples	Mean	Standard Deviation	P-Value
Group IV	10	60.02	5.74	0.014*
Group V	10	49.56	11.02	
Group IV	10	60.02	5.74	0.925
group VI	10	60.29	6.95	
Group V	10	49.56	11.02	0.016*
Group VI	10	60.29	6.95	

* Note : If P value is < 0.05, then the difference between the mean values are statistically significant

** denotes statistically highly significant (P-value <0.001)

INFERENCE: The mean difference between Groups IV & V, Groups IV & VI and Groups V & VI by using the Post-hoc analysis (Tukey-HSD procedure) the results of Groups IV & V and Groups V & VI were found to be statistically significant (P value < 0.05), Groups IV & VI were found to be statistically insignificant (P-value >0.05)

Table 11 Comparison of mean tensile bond strength of Groups I & IV, Groups II & V and Groups III& VI using Tukey-HSD procedure (between polymeric implant cement and non-eugenol zinc oxide cement)

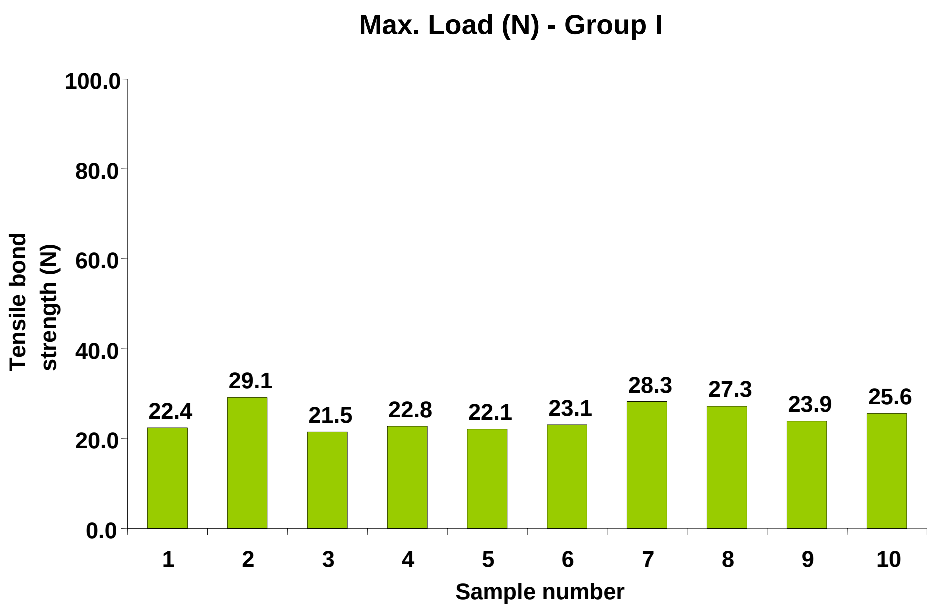
Group	Cement	Number of samples	Mean	Standard Deviation	P-Value
Groups I &IV (retentive grooves)	Non Eugenol Zinc Oxide cement	10	24.60	2.76	0.001**
	Polymeric Implant cement	10	60.02	5.74	
Groups II&V (tungsten carbide bur)	Non Eugenol Zinc Oxide	10	26.74	4.92	0.031*
	Polymeric Implant cement	10	49.56	11.02	
Groups III & VI (diamond abrasive)	Non Eugenol Zinc Oxide cement	10	47.37	6.59	0.001**
	Polymeric Implant cement	10	60.29	6.95	

* Note : If P value is < 0.05 then mean values are statistically significant

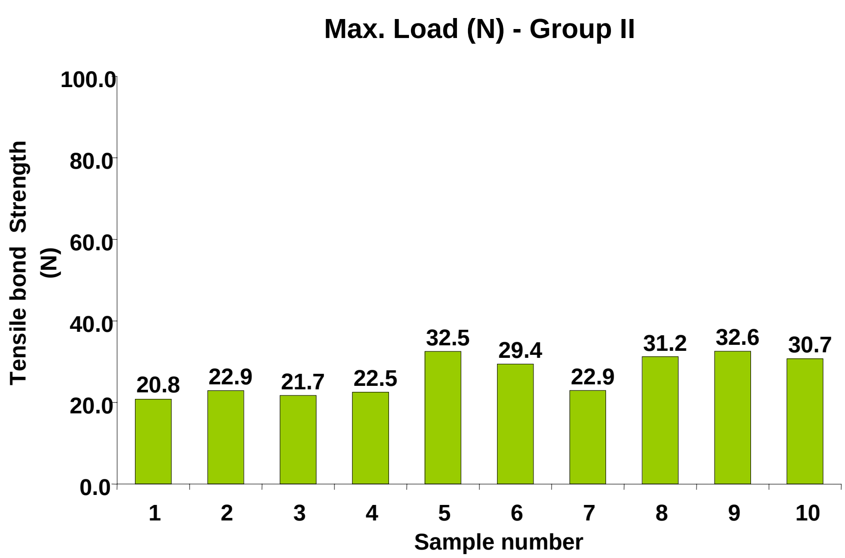
** denotes statistically highly significant (P-value <0.001)

INFERENCE: The mean difference between Groups I & IV, Groups II & V and Groups III & VI by using the Post-hoc analysis (Tukey-HSD procedure) the results of Groups I & IV, Groups II & V and Groups III & VI was found to be statistically significant. The mean tensile bond strength obtained with polymeric implant with three surface modifications of PEEK abutments was statistically significantly higher than that of non-eugenol zinc oxide cement.

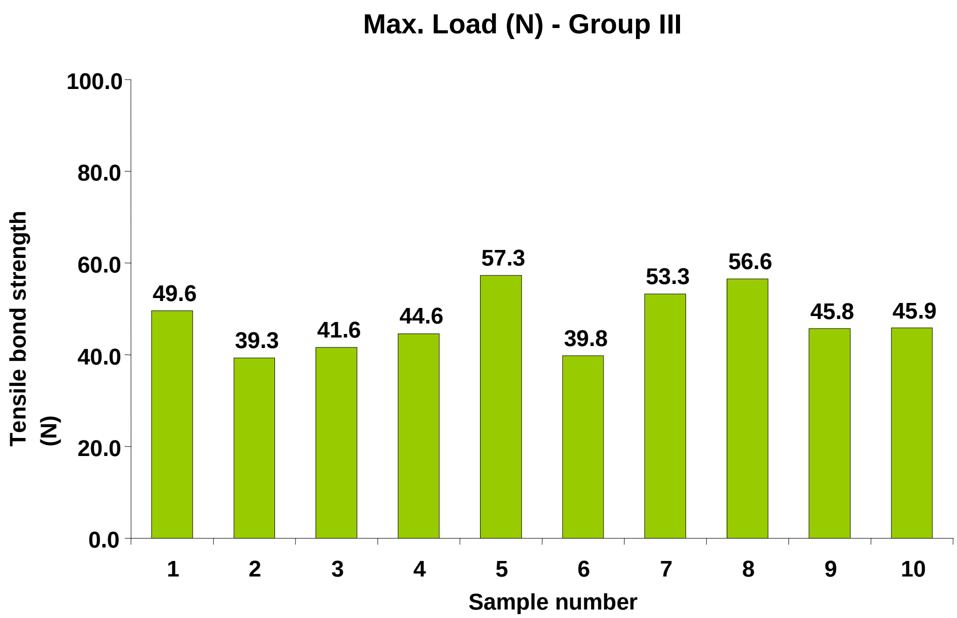
Graph 1 Basic data of tensile bond strength of Group I (PEEK abutments with retentive grooves and luted with non-eugenol zinc oxide cement) samples



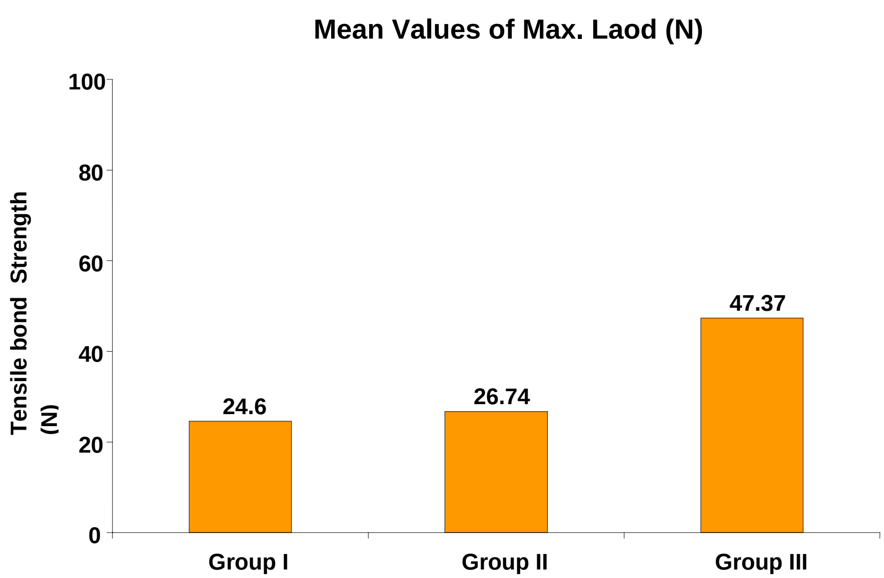
Graph 2 Basic data of tensile bond strength of Group II (PEEK abutments milled with tungsten carbide bur, air abraded and luted with non-eugenol zinc oxide cement) samples



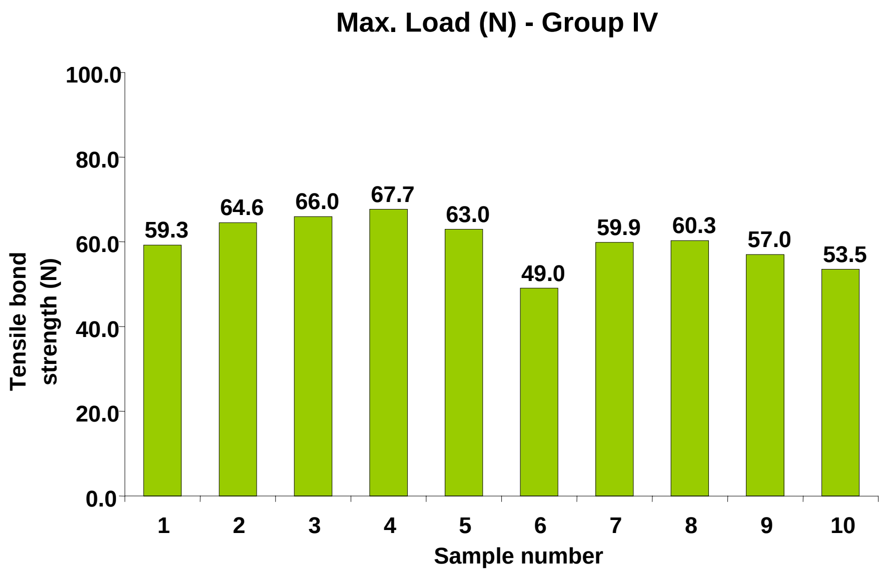
Graph 3 Basic data of tensile bond strength of Group III (PEEK abutments milled with diamond abrasive and luted with non-eugenol zinc oxide cement) samples



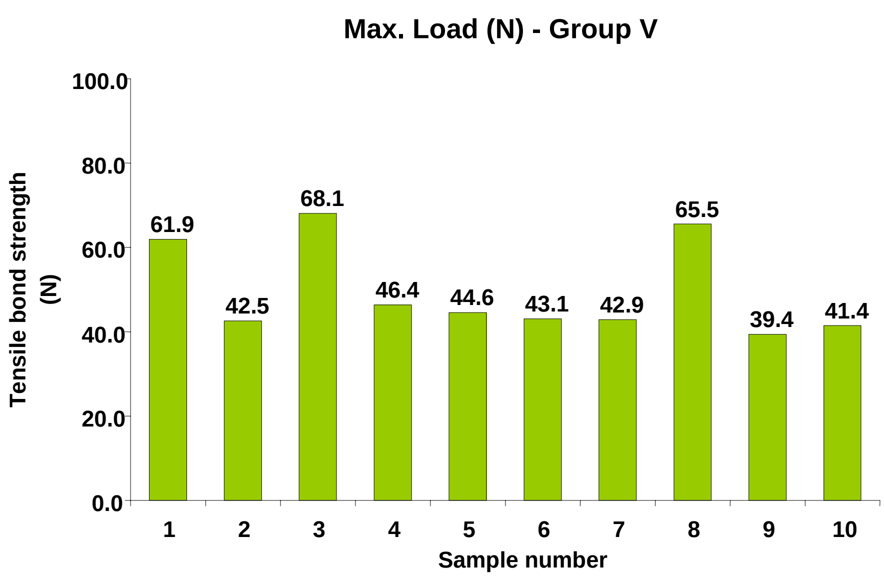
Graph 4 Comparison of mean tensile bond strength of Groups I, II & III**.**



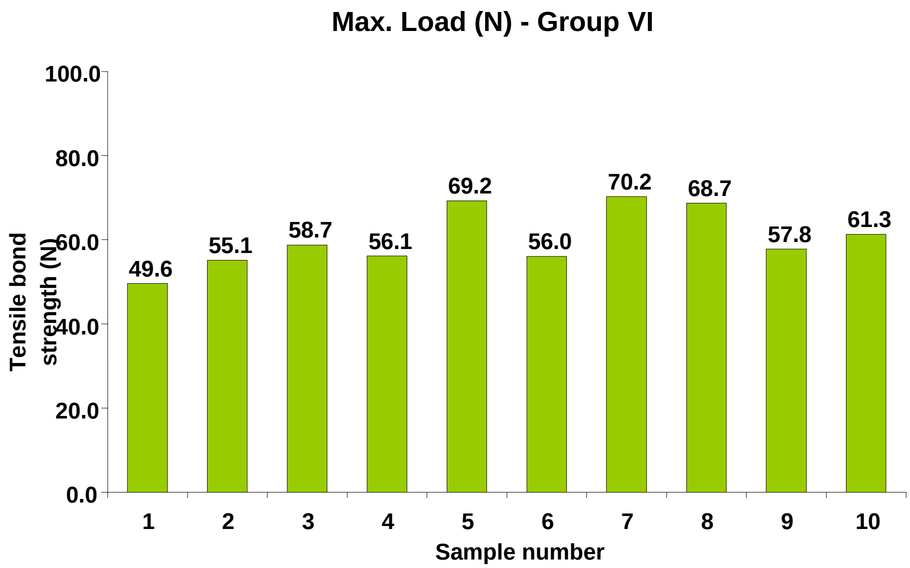
Graph 5 Basic data of tensile bond strength of Group IV (PEEK abutments with retentive grooves and luted with polymeric implant cement) samples



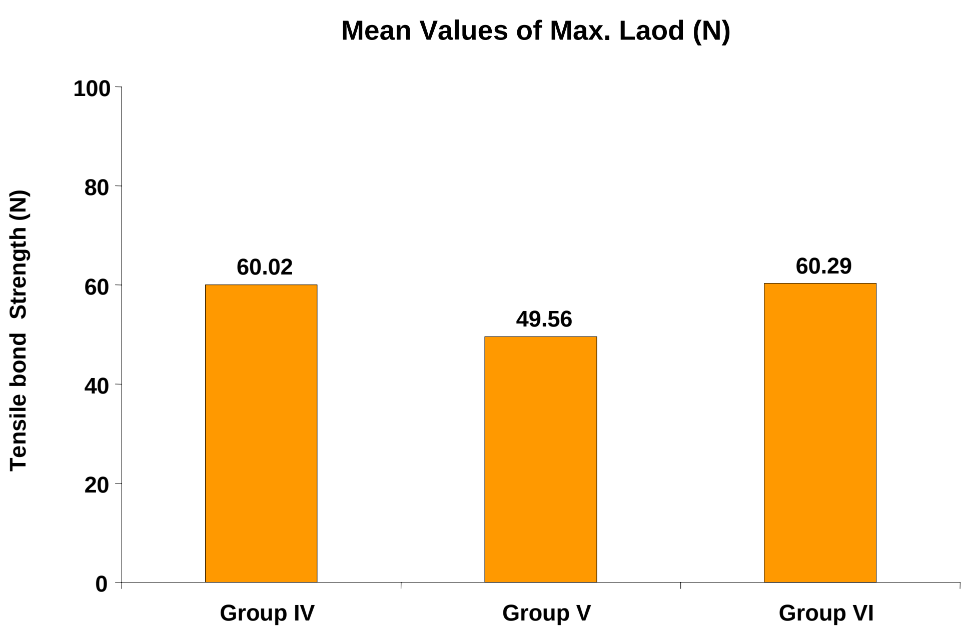
Graph 6 Basic data of tensile bond strength of Group V (PEEK abutments milled with tungsten carbide bur, air abraded and luted with polymeric implant cement) samples



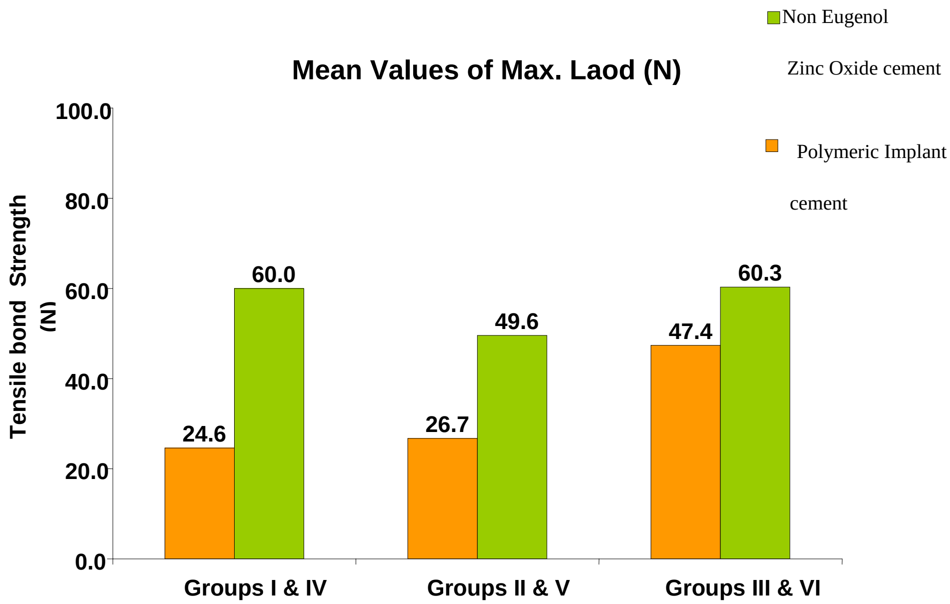
Graph 7 Basic data of tensile bond strength of Group VI (PEEK abutments milled with diamond abrasive, and luted with polymeric implant cement) samples



Graph 8 Comparison of mean tensile bond strength of Groups IV, V & VI



Graph 9 Comparison of mean tensile bond strength of Groups I & IV, II & V, III & VI



Qualitative analysis of PEEK abutments test samples by scanning electron microscope(SEM) under 2000X magnification:

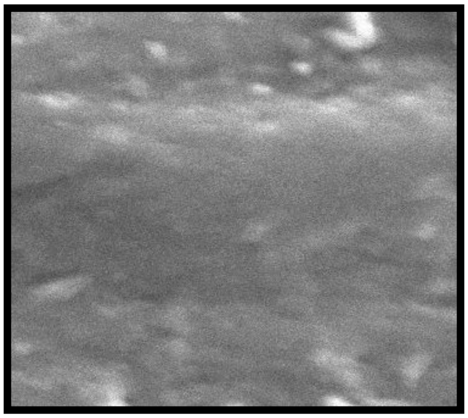


Fig.29: SEM photomicrograph Groups I and IV (PEEK abutment with retentive grooves) samples revealed minimal surface irregularities

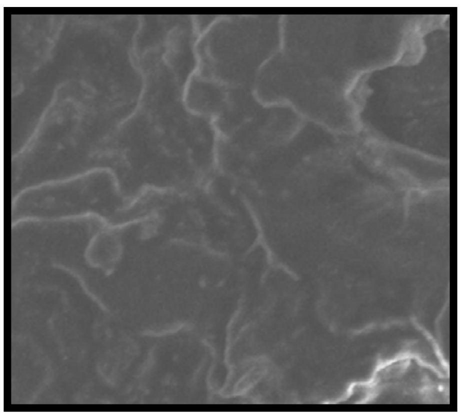


Fig.30: SEM photomicrograph Groups II and V (PEEK abutment milled with tungsten carbide bur and air abraded with 110µm) revealed moderate presence of surface irregularities in the form of peaks, valleys and pores

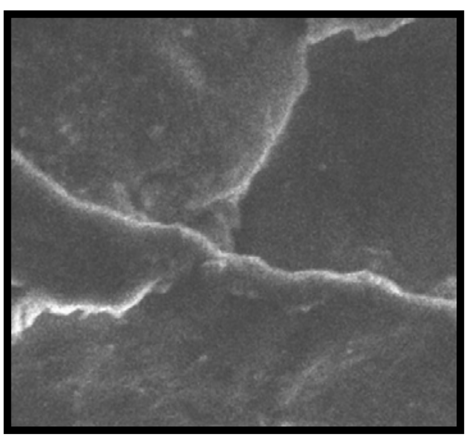


Fig.31: SEM photomicrograph Groups III and VI (PEEK abutment milled with diamond abrasive) samples revealed maximum of surface irregularities in the form of increased presence of peaks, valleys and pores

DISCUSSION

The success of implant supported restoration mainly depends on retention of prosthesis. The mode of retention for fixed prosthesis can be either cement retained or screw retained or combination of both. The factors influencing the selection of mode of retention include abutment occlusal convergence, surface area and height, surface modification and type of cement.[3,29,39,52]

Use of cement-retained, implant-supported restoration has increased, due in part to the ability to optimize occlusal interdigitation, improved esthetics and correct loading characteristics. One of the major concerns with cement-retained implant-supported restorations is the challenge of prosthesis retrievability when abutment screw loosens. In cement-retained implant-supported restorations, the amount of force required for retention as well as to retrieve the implant-supported restorations are dependent on the abutment configuration, design, abutment height, surface modification, and type of cement.[3,29,52]

Numerous studies have been carried out to test the retention offered by various cements available in the market.The choice of cement for an implant supported restoration should be based on the need or desire for retrivability , the anticipated amount of retention needed, the ease of cement removal, should be easy to manipulate and remove without damaging implant components and should not cause peri implant complication. Literature shows the use of both provisional cements and definitive cements for the cementation of implant supported fixed prosthesis. Some authors advocated the use of provisional cements to maintain retrievability based on assumption that provisional cements are less retentive than permanent cements.[3,5,6,10, 29,33,34 ,48, 52, 54]

The most common failure in cement retained restorations were cement washout and loose abutment screw. Study on leakage of various types of luting agents and conclude that the zinc oxide-eugenol cement showed increased leakage with time. Intra oral study evaluated resin, polyurethane, and eugenol-containing provisional luting agents and reported that the eugenol-containing luting agents were most soluble. Therefore the problems encountered with provisional cements are insufficient strength to resist functional force and cement washout at the margin of the abutment or crown interface resulting in marginal leakage and bacterial proliferation. Study reported that polyurethane and resin cements are typically stable intraorally. Thus it is anticipated that the cement gap and tensile bond strength of these luting agents would change less over time. The ability of resin based provisional cements to achieve good bond strength with metallic abutments and their ability to remain stable intra orally makes them a good choice for cementing medium.[35,40,48,53]

The influence of PEEK abutment surface roughness, and the presence of retentive grooves in increasing the retention of the implant restoration have been documented but studies on abutment surface modifications to aid retention are limited. This study was carried out to find the effect of different surface modifications of abutment on the retention of implant supported restoration when using a non eugenol zinc oxide cement polymeric implant cement.[18,21,31,43,50]

In this study, provisional PEEK abutments (Fig.1d)as supplied by the manufacturer, machined 7mm high, 2^0 taper circumferentially, with five retentive grooves of 0.5mm depth each were used in Group I and Group IV(Fig.8). Millings of PEEK implant abutments were done in most clinical situations in order to achieve parallelism of abutments. In Groups II and V the PEEK implant abutment surface were milled with tungsten carbide bur (Fig.7c) and air abraded with 110 µm aluminum oxide(Fig. 9b) with 2^0 taper to evaluate the retentive bond strength on milled abutment to resemble a clinical situation(Fig.8b). In Groups III and VI, abutments were milled with diamond abrasive (Fig.7b) to test its influence on the retention of the restoration.(Fig.8c)

The surface modified PEEK abutments were analyzed by scanning electron microscope (SEM) (Fig.10). The specimens were examined at a magnification of 2000X. The SEM photomicrographs revealed significant variation in the surface morphology of surface modifications on PEEK abutments and PEEK abutments with retentive grooves. PEEK abutments milled with diamond abrasive showed maximum surface irregularities in the form of peaks, valleys and pores. (Fig.31). PEEK abutments milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide showed lesser surface irregularities compared to milled PEEK abutments with diamond abrasive. (Fig.30) PEEK abutments with retentive grooves showed parallel grooves with minimal surface irregularities. (Fig.29)

The acrylic resin copings were fabricated with the help of index (Fig.14) and finishing of the acrylic copings were done as usual manner. The acrylic copings were cemented on implant abutment with non-eugenol zinc oxide cement (Fig.16a) or polymeric implant cement(Fig.17a). Non-eugenol zinc oxide cement was mixed manually (Fig.16d) and Polymeric Implant cement was dispensed by auto-mixing tips (Fig.17b). Both cements dispensed onto the intaglio surface of the copings and cemented onto the abutments with a load of 2 kg with the help of the surveyor for a period of 10 mins. (Fig.21) Following bonding procedure the samples were stored in artificial saliva (Fig.22)at room temperature for 24 hours. (Fig.23)

The samples were tested on universal mechanical testing machine (Lloyd instruments, Farnham, U.K.) (Fig. 25) with a 500kg load cell at a crosshead speed of 5mm/min, until the coping debonded from the abutments. From this the ultimate tensile strength was recorded in newton.

The mean and standard deviation estimated from the samples for each groups was statistically analyzed. Mean values were compared by one-way analysis of variance (ANOVA). Multiple range tests by Tukey-HSD procedure was employed to identify the significant groups at 5% level.

For non eugenol zinc oxide cement, comparison between the surface modifications, the highest value of mean of tensile bond strength of 47.37 newton (Group III) (Table 3)was obtained for the PEEK implant abutment surface milled with diamond abrasive followed by PEEK abutments surface milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide 26.74 newton (Group II) (Table 2)and PEEK abutment with retentive grooves (Group I) (Table 1) 24.60 newton respectively. For Polymeric Implant cement, comparison between the surface modified PEEK provisional abutments, the highest value of mean of tensile bond strength of 60.29 newton (Group VI) (Table 8) was obtained for the PEEK implant abutment surface milled with diamond abrasive followed by PEEK abutments with retentive grooves 60.02 newton (Group IV) (Table 6) and abutments were milled with tungsten carbide and air abraded with 110 µm aluminum oxide (Group V) (Table7) 49.56 newton respectively

The bond strength value obtained in this study for the PEEK abutments samples with retentive grooves (Group I- non eugenol zinc oxide cement and Group IV - polymeric implant cement) were 24.60 and 60.29 newton. (Table 11) This was due to the mechanical retention on abutments by means of horizontal retentive grooves. The retentive grooves present on implant abutments were five in numbers and 0.5mm in depth. The bond strength value obtained for the PEEK abutment milled with tungsten carbide and air abraded with 110 µm aluminum oxide (Group II- non eugenol zinc oxide cement and Group V – polymeric implant cement) (Table 11) were 26.74 and 49.56 newton. But the bond strength value obtained for the PEEK implant abutments milled with diamond abrasive (Group III- non eugenol zinc oxide cement and Group VI - polymeric implant cement) were 47.37 and 60.29 newton respectively(Table 11). This could be due to increase in surface area, which helps micromechanical bonding of the cement and thus increasing retention.

Comparison of mean tensile bond strength of the Groups I II & III using Tukey-HSD procedure (non eugenol zinc oxide cement) (Table 4), the mean difference between Groups I & II, Groups I & III and Groups II & III the results of Groups I & II was found to be statistically insignificant and Groups I & III and Groups II & III were found to be statistically significant. (Table 5)

Comparison of mean tensile bond strength of the Group IV V & VI using Tukey-HSD procedure (polymeric implant cement) (Table 9)the mean difference between Groups IV & V, Groups V & VI , the results of Groups IV & V and Groups V& VI were found to be statistically significant, Groups IV & VI were found to be statistically insignificant.(Table 10)

The mean difference between Groups I & IV, Groups II & V and Groups III & VI by using the Post-hoc analysis (Tukey-HSD procedure) the results of Groups I & IV, Groups II & V and Groups III & VI was found to be statistically significant(Table 11)

For the fracture analysis, samples of Groups I, II and III cemented with non eugenol zinc oxide cement, cohesive and adhesive bond failures occurring at the interface of cement, abutments and interface of acrylic copings. (Fig.27) But in samples of Groups IV, V and VI, cemented with polymeric implant cement, adhesive bond failures occurring at the interface of cement and the abutments(Fig.28). The difference in bond strength of the cement to PEEK abutments and auto polymerizing acrylic copings needs to be studied to understand this failure. Considering the advantages obtained by surface modifications of abutments, the provisional cement itself can be used for luting purpose and retention offered was comparable to resin cement. In addition retention achieved with diamond abrasive will be of use in situation when clinical abutment height is to be reduced. Thus the results showed that in both the groups utilizing the non eugenol zinc oxide cement and polymeric implant cement, the surface modified PEEK abutment with diamond abrasive had the highest mean tensile bond strength. However in the non eugenol zinc oxide eugenol cement groups the results of the tungsten carbide bur had statistically higher mean tensile bond strength than that of retentive grooves. With the polymeric implant cement, the retentive grooves had a statistically higher mean tensile bond strength than tungsten carbide bur. Thus further research needs to be conducted to evaluate the chemical and mechanical properties for the above difference.

A further short coming of this study was lack of artificial aging by thermo cycling, to test its influence on retention of restoration. Further research is required for evaluating the use of PEEK as definitive implant abutment and also its bond between metal copings.

Additional studies are required to investigate the mechanical resistance of PEEK abutments and marginal leakage under clinical loading conditions.

CONCLUSION

The following conclusions were obtained from the present in vitro study which was conducted to comparatively evaluate the effect of surface modifications of PEEK abutments on the retention of implant-supported provisional restorations luted with two different luting agents:

1. The mean tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations on PEEK implant abutments with retentive grooves (Group I) was found to be 24.60 N.
2. The mean tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations on PEEK implant abutments milled with tungsten carbide bur and air abraded with 110 μm aluminum oxide (Group II) was found to be 26.74 N.
3. The mean tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations on PEEK implant abutments milled with diamond abrasive (Group III) was found to be 47.37N.
4. On comparison, the mean tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations on PEEK implant abutments subjected to three different surface modifications (Groups I, II and III) were found to be statistically highly significant between the three groups. (P-value <0.001).

The mean tensile bond strength of Group II samples was marginally higher than that of Group I samples which was statistically insignificant (P-value >0.05).

Group I = Group II

The mean tensile bond strength of Group III samples was statistically significantly higher than that of Groups I & II (P-value <0.001).

Group III > Group I & Group II

5. The mean tensile bond strength of polymeric implant cement used for luting the provisional restorations on PEEK implant abutments with retentive grooves (Group IV) was found to be 60.02 N.
6. The mean tensile bond strength of polymeric implant cement used for luting the provisional restorations on PEEK implant abutments milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide (Group V) was found to be 49.56 N.
7. The mean tensile bond strength of polymeric implant cement used for luting the provisional restorations on PEEK implant abutments milled with diamond abrasive (Group VI) was found to be 60.29 N.
8. On comparison, the mean tensile bond strength of polymeric implant cement used for luting the provisional restorations on PEEK implant abutments subjected to three different surface modifications (Groups IV, V and VI) were found to be statistically significant between the three groups.The mean tensile bond strengths of Group IV and VI

samples were found to be statistically insignificant (P-value > 0.05).

Group IV = Group VI

The mean tensile bond strength of Group V samples was statistically significantly lesser than that of Group IV and Group VI samples (P-value <0.05)

Group VI = Group IV > Group V

9. The mean tensile bond strength of Group IV samples(retentive grooves on PEEK abutments - polymeric implant cement) was found to be statistically significantly higher compared to Group I samples (retentive grooves on PEEK abutments – non-eugenol zinc oxide cement) (P-value <0.001)

Group IV > Group I

10. The mean tensile bond strength of Group V samples(milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide on PEEK abutments - polymeric implant cement) was found to be statistically significantly higher compared to Group II samples (milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide on PEEK abutments – non-eugenol zinc oxide cement) (P-value <0.05)

Group V > Group II

11. The mean tensile bond strength of Group VI samples(milled with diamond abrasive on PEEK abutments - polymeric implant cement)

was found to be statistically significantly higher compared to Group III samples (milled with diamond abrasive on PEEK abutments – non-eugenol zinc oxide cement) (P-value <0.001)

Group VI > Group I

12. On overall comparison, the mean tensile bond strength of polymeric implant cement for the three different surface modifications (Groups IV, V & VI) were found to be statistically significantly higher as compared to the mean tensile bond strength of non-eugenol zinc oxide cement for the three different surface modifications (Groups IV, V & VI)

The mean tensile bond strength of polymeric implant cement used for luting the provisional restorations milled with diamond abrasive on PEEK abutments was statistically found to be equal with retentive grooves on PEEK abutments and higher than that with tungsten carbide burs.

The mean tensile bond strength of non-eugenol zinc oxide cement used for luting the provisional restorations milled with the diamond abrasive on PEEK abutments was statistically higher when compared with PEEK abutments milled with tungsten carbide bur and retentive grooves.

13. Qualitative evaluation the surface of PEEK abutments of Groups I and IV with retentive grooves as visualized under scanning microscope (SEM) of 2000X magnification revealed minimal surface irregularities.
14. Qualitative evaluation the surface of PEEK abutments of Groups II and V milled with tungsten carbide and air abraded with aluminum oxide110 µm as visualized under scanning microscope (SEM) of 2000X magnification revealed moderate presence of surface irregularities in the form of peaks, valleys and pores than Groups I & IV.
15. Qualitative evaluation the surface of PEEK abutments of Groups III and VI milled with diamond abrasive as visualized under scanning microscope (SEM) of 2000X magnification revealed maximum surface irregularities in the form of increased presence of peaks, valleys and pores than Groups I, II, IV & V
16. The SEM study of the PEEK abutment with diamond abrasive had shown maximum surface irregularities in the form of peaks, valleys and pores. This factor can be correlated with the result of this study in which the diamond abrasive surface modifications of PEEK abutment exhibited highest tensile bond strength when the provisional restorations are luted with non-eugenol zinc oxide cement as well as polymeric implant cement.

SUMMARY

This in vitro study was conducted to comparatively evaluate the effects of surface modifications of PEEK abutments on the retention of implant supported provisional restorations luted with two different luting agents.

A total of sixty PEEK implant abutments with dimension of 7mm height and 2^0 occlusal convergence and sixty implant analogs were used. Implant analogs were embedded in clear auto polymerizing resin blocks. The PEEK abutments were fastened to the respective Implant analogs and divided into six groups of ten samples each. In Groups I and IV, abutments with retentive grooves were used. In Groups II and V, abutments were milled with tungsten carbide bur and air abraded with 110 µm aluminum oxide and in Groups III and VI, abutments were milled with diamond abrasive.Wax patterns were made with inlay wax on the PEEK abutments and index were designed for the fabrication of acrylic copings.

An additional three PEEK abutments were selected for surface analysis using scanning electron microscope (SEM) with each type of the above mentioned surfaces.

The provisional restorations were fabricated with tooth colored auto polymerizing acrylic resin. They were then cemented onto the respective abutments with non eugenol zinc oxide cement in Groups I, II and III and polymeric implant cement in Groups IV, V and VI. The test samples with the provisional restorations were kept in artificial saliva for 24 hours for aging at room temperature to simulate the oral condition. The cemented test samples

were tested for tensile bond strength with a universal testing machine and the basic values were recorded for all the six test groups. The result were subjected for statistical analysis.

On comparative evaluation of the effect of three different surface modifications, the PEEK implant abutments modified with diamond abrasive exhibited statistically significantly highest tensile bond strength when the provisional restorations were luted with non eugenol zinc oxide cement. However PEEK implant abutments modified with tungsten carbide bur and PEEK implant abutments with retentive grooves exhibited statistically equal bond strength values to each other but lesser than that of PEEK abutments modified with diamond abrasive.

On comparative evaluation of the effect of three different surface modifications, the PEEK implant abutments modified with diamond abrasive exhibited statistically significantly higher tensile bond strength values equivalent to the values exhibited by PEEK abutments modified with retentive grooves, when the provisional restorations were luted with polymeric implant cement. However PEEK implant abutments modified with tungsten carbide bur exhibited statistically lesser tensile bond strength values.

On comparison of the two different cements used in the study, the polymeric implant cement exhibited a statistically significantly higher tensile bond strength values with all the three surface modifications of PEEK abutments compared to the non-eugenol zinc oxide cement.

On comparative evaluation of the effect of three different surface modifications on PEEK implant abutments on the retention of implant supported provisional restorations luted with two different luting agents, namely non eugenol zinc oxide cement and polymeric implant cement, the diamond abrasive surface modifications of PEEK abutments exhibited statistically significantly highest tensile bond strength. These results are in correlation with the SEM analysis of surface modified PEEK abutments.

A fixed provisional implant restorations provides the most esthetic, stable and desirable result for the patient. The newly designed PEEK provisional abutments provide a lower cost option for fixed restoration. This abutment was cost effective and can be easily modified. It supports a transitional prosthesis that is delivered at the time of implant placement to achieve acceptable esthetics, function, and most importantly it maintains the patients self esteem and self confidence. Further studies are required to investigate the mechanical resistance of PEEK abutments and marginal leakage under clinical loading conditions.

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